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Surveys to determine the sanitary condition of polluted streams may be undertaken for any one or a combination of several purposes. The nature of the organization required to conduct such a survey as well as the survey itself is then very largely dependent upon the kind of information desired. It is, therefore, highly essential that a clear and complete statement of the objectives be agreed upon first; then the plans for the survey can be built around these requirements. It is not possible to enumerate all of the purposes which stream surveys may be designed to accomplish but they include the securing of specific information to ascertain:

1. The nature and extent of nuisance conditions resulting from odors, sludge deposits along channels and shore lines, floating sleek, grease and oil and objectionable discolorations and aquatic growths.

2. Suitability of the stream waters for public or industrial water supply, including the possibilities and probable costs of treatment, chemical and biological characteristics and adequacy of flow.

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3. The capacity of the watercourse for sewage or industrial waste dilution which is dependent on volume and constancy of flow, extent of the oxygen reserve, degree of sedimentation in the channel and rates of recovery from pollution.

4. Ability to support fish and other aquatic life as it may be affected by the content of toxic substances, the oxygen balance and existence of plant and other fish food.

5. Safety for recreational use which involves the relative freedom from pathogenic bacteria and suspended solids.

6. General relationships of pollutional factors for application to a variety of specific conditions. These relationships include the correlation of known populations and industrial wastes with water quality of the receiving stream, the rates of recovery from determinable pollution under known conditions of depth, velocity and temperature of the flowing water and the nature and direction of changes in the bacterial, biological and oxygen content and their inter-reactions.

The information needed to fulfill these general requirements falls into one of three general classes. The first class deals with the nature, location and extent of sources of pollution of the stream under investigation, which involves a sanitary survey of the watershed to determine the distribution of the population both sewered and unsewered, the extent of sewage treatment, the location, types and volumes of industrial waste contributions and similar matters. The second general class of information embraces the

hydrometric factors such as the daily volume of flow of the main stream at definite points and of the tributaries at their mouths, the times of flow between different locations and the records of rainfall and its relation to runoff. The third type of essential data is concerned with the sanitary condition of the water and sediments throughout the channel under varying conditions of stream flow, temperature and season. Securing of this class of information usually involves laboratory examination of a variety of samples over an extended period of time.

The relative amount of time to be spent on the assembling of information of these three general types will be governed very largely by the specific objectives of the study. The nature of the organization in turn, will depend upon the emphasis to be placed on these respective classes of data. It will depend further upon the extent of information readily obtainable from existing governmental agencies, Federal, State and municipal which in many cases will be found to have extensive collections of pertinent data. Close contact and co-operation with such agencies is, therefore, highly essential in any stream pollution survey and time will be well spent in first assembling and correlating this available material. Frequently, also, active cooperation can be obtained from these organizations particularly when the results can be made of value to them.

Organization.

Because the complete stream survey requires a wide variety of technical knowledge, the personnel employed will be composed of a number of professional groups, including sanitary engineers, bac-

teriologists, chemists and biologists. The amount of service required of each of these groups will depend upon the extent of the particular problem and the thoroughness of the survey. Proper facilities for the collection, review and filing of collected data are essential for orderly work. Adequate time should be permitted for the critical study of the accumulated material and preparation of a comprehensive report following the conclusion of actual field work. The entire activity will be judged largely by the thoroughness of the finished product - the report - which constitutes the only generally available permanent record.

Conduct of the Pollution Survey.

It is generally advisable to locate a field headquarters and laboratory close to the stream to be studied and readily accessible to a maximum of stream length. In this way samples can be examined promptly after collection, hydrometric studies may be carried on to advantage including the operation and maintenance of stream gages and special problems of domestic and industrial waste pollution may be investigated during the course of the routine field work. The location should be selected with consideration to the availability of water, gas and electric current for laboratory use, railway and highway for transportation of needed materials and supplies and highway connections for prompt delivery of samples from the stream sampling stations.

The Sanitary Survey. Determination of the nature and extent of sources of pollution is largely a task of assembling available information from different agencies and filling in the gaps by

original investigation. Distribution and density of urban and rural population on any watershed can be computed by employing the published reports of the U. S. Census Bureau and a large scale map showing all political subdivisions and drainage areas of the watershed. State governmental agencies, particularly State health departments, usually have extensive data on sewered populations, nature and extent of sewage treatment and types, sizes and products of industrial establishments particularly those discharging objectionable liquid wastes. It is sometimes necessary to undertake special surveys of representative industrial plants to gage waste discharges and collect samples for analysis for correlation with raw material, production or employee statistics. The amount of this work often may be reduced greatly by applying conversion factors thus developed for a representative plant to the wastes of all plants of this particular type of industry on the watershed.

Hydrometric Relationships. The hydrometric study should be conducted in sufficient detail to supply information on the daily volume of stream flow at each sampling station and at each point of significant pollution throughout the period of collection and analysis of samples. The velocity of flow between sampling stations and mouths of principal tributaries throughout the range of gage height fluctuations is also important in connection with the rapidity of travel of pollutional substances down stream. Basic data on stream flow can generally be obtained from the U. S. Geological Survey or if such gagings have not been made, co-operative arrangements can be worked out with that organization for the placing and maintenance of recording or other gages at the proper locations and

the establishment of rating stations from which daily stream flows can be computed for the main stream and its principal tributaries. The District Engineers of the Geological Survey can give most helpful advice also on methods of computation of stream flows from gage height-rating curve relationships and on the determination of velocities of flow and other essential hydrometric procedures. Velocities of flow may be determined by any of several different methods and the one to be selected will be dependent upon the type of stream under observation and the extent of available knowledge of the stream channel. For large rivers, where accurate information on channel cross sections, stream profiles and gage height records is available, the displacement method as used in our Ohio River(1) and Illinois River(2) studies is perhaps the most dependable. For smaller streams, observations of the velocities of travel of floats, dyes, salt solution or other materials in the water through selected river stretches can be used. Wave crest travel(3) also has been suggested as a method of computing flow velocities but is not yet in general use. Diurnal variations in the chloride content as contributed by domestic sewage might be used also over considerable stretches of streams where the volume of sewage is large in proportion to the normal stream flow. Organizations concerned with flood control planning and construction, including the U. S. Army Engineers, State Planning and Water Conservation agencies are assembling extensive data that may be found most useful for this purpose.

Rainfall and weather records are also helpful in completing the hydrometric studies and for determining the relationship between rainfall and runoff in the different sections of the watershed. Pre-

cipitation data are generally obtainable from the U.S. Weather Bureau and, where necessary, cooperative arrangements should be considered for increasing the number of rainfall observation stations on the watershed to be surveyed.

These hydrometric data should be collected and arranged with the specific objective of ascertaining the extent of natural dilution that is provided in comparison with the natural purification of contributed pollution that is occurring under varying conditions of stream flow. From the combination of these factors, the reserve capacity of the stream for additional pollution or the extent of pollution overload can be estimated and consequently the degree of purification of domestic sewage and industrial wastes determined that must be provided at each point in order to maintain the stream in the desired sanitary condition.

Sanitary Condition of the Water. Determination of the extent of pollution of any body of water usually involves the examination of samples of the contributed polluting constituents and of the water and of bottom sediments of the channel collected throughout a sufficient period of time to take into account seasonal fluctuations in flow, variations in rates of natural purification and other changing factors. It is generally best to establish definite points for the collection of samples rather than to depend upon random collections from indiscriminate locations. Such stations should be carefully selected with due regard to sources of pollution, mouths of tributaries, accessibility of transport to field laboratories and representative sections of stream. In many streams

highway and railroad bridges determine the location of sampling stations. In large rivers boats are frequently necessary to reach the desired points. In moderate or small streams one sample at mid-depth is usually representative of the cross section. In large rivers such as the Ohio and Illinois, we collected three samples on a cross section, each at the center of gravity of each third of the wetted cross sectional area. These samples were at first analysed separately and the results averaged. Later, to reduce the amount of laboratory work, the three samples were composited and the composite analysed. Comparison of the results by both methods indicated very little variation in the figures obtained. In our study of Lake Michigan(4), the water area under investigation was divided up by a grid of intersecting sight lines and samples collected at these intersections. Collections of water samples are generally made with the aid of some device that will permit obtaining the sample at any desired depth and in the amounts required for all analytical examinations. Sediment samples can be obtained with a mud scoop or various types of equipment which remove intact a section of deposit from the channel bottom.

The method of transport of samples to the field laboratory will depend on local facilities. In any event samples should be delivered as quickly as possible after collection and a maximum elapsed time should be established, not to exceed six hours. In warm weather it is desirable to ice all samples either by packing them in ice or in a chilled container. Good highways, when available, greatly facilitate the speedy transportation of samples by the sample collector himself and correspondingly extend the range of

service of the field laboratory. In special cases bus or railway express transport service is cheapest engaging the part-time services of persons in the vicinity of the sampling stations as collectors and shippers.

There are three general types of examination to which polluted water samples may be submitted; bacteriological, biological and chemical including biochemical. The laboratory equipment and personnel required for performing these tests will be governed by the number of samples to be examined daily and the tests which each sample will undergo. A good general rule to follow is to examine more frequent samples from a few well selected sampling stations than a few samples from too large a number of sampling stations. Equipment should be ample but not necessarily elaborate. Much time is saved by an adequate supply of laboratory glassware. Reagents and culture media should be standardized and distributed from the central laboratory to insure uniformity of results. Dehydrated culture media can now be purchased in single lots in quantities sufficient for any reasonable field study. The amounts and nature of equipment and supplies required to operate chemical and bacteriological laboratories of various sizes are given in various laboratory texts. Itemized lists which we have found satisfactory for routine laboratory examination of water and sewage samples have been compiled for our use, copies of which are available on application.

Professional personnel trained in the standardized technique of water examination are essential for the best results. Analytical procedures should conform strictly to the Standard Methods adopted

jointly by the American Public Health and American Water Works Associations in order that the finished results may be comparable with those of other workers. Any deviations from these accepted methods, however slight, should be described in detail. The range of analytical tests of samples will depend upon the planned thoroughness of the pollution study and its objectives. The minimum of bacteriological tests would include the determination of coliform group organisms and in special instances, plate counts on agar incubated at 37°C. for 24 hours. The chemical examinations as a minimum should include turbidity, hydrogen ion concentration, dissolved oxygen and 5-day biochemical oxygen demand. Plankton examinations should distinguish the relative numbers of pollution indicator organisms both free floating and in bottom sediments and be made at sufficiently frequent intervals to record the pulses of various indicator forms as they occur during the progress of the seasons. Usually, weekly examinations of water samples and monthly examinations of bottom sediments will meet these requirements.

For more comprehensive studies this laboratory work can be expanded. Thus, in our Scioto River study now in progress, some additional analytical tests are conducted. For the determination of coliform organisms lactose broth followed by 2 per cent brilliant green bile is employed for the confirmed test. In addition one confirmed sample, rotated daily, is carried to completion through Endo, second lactose broth, second Endo and agar slant for gram stain, purity and spore test. The total bacterial colony count is made for each sample also, using agar plates incubated at 37°C. for 24 hours. The routine chemical tests on each sample include turbidity,

hydrogen ion concentration, dissolved oxygen, 5-day biochemical oxygen demand, suspended solids and alkalinity. To further trace the course of oxidation, one sample, rotated each day, is put up for determination of the 3-, 5-, 7-, 10-, 12-, 15-, 20- and 25-day oxygen demand.

In addition, samples from selected stations are composited over a period of one month, preserved by sulphuric acid, and then shipped to our central laboratory for determination of nitrites, nitrates, ammonia and organic nitrogen.

The biological examination consists in the determination of the plankton content of water samples collected bi-weekly, preserved in 6 per cent formalin and shipped to our central laboratory. On alternate weeks similar samples are examined, without the use of preservative, at our Chillicothe field laboratory. Sediment samples are collected once each month, preserved by formalin, and shipped to our headquarters laboratory for determination of pollution indicator organisms.

With the constant accumulation of survey and laboratory data, some attention should be paid to the maintenance and filing of proper current records, summaries and progress reports. Frequent, careful reviews of the trend of results will indicate the advisability of changes in field methods, relocation, omission or addition of certain sampling stations, recurring errors in sampling or laboratory technique and various other modifications in procedure that unless made early in the field study, will greatly detract from the value of the completed work.

The most difficult feature, perhaps of any stream pollution survey is the critical weighing of all the evidence, the derivation of conclusions based on this evidence and the presentation of this material in concise, understandable form. Too much time and concentration cannot be devoted to this part of the survey when it is remembered that the finished report will be the only permanent record generally available. Every effort should be made, therefore, to derive from the carefully summarized data all the pertinent facts which they contain, to point them out in their logical sequence and to draw from them unbiased, logical conclusions that are well substantiated. Usually it will be advisable to limit the tabulated material to monthly or periodic averages rather than to publish tables of detailed analytical results. Diagrams, illustrative of outstanding trends are most helpful in reinforcing the text. Photographs have a place in reports prepared for the general reader. Pollution surveys thus reported are of more than local value; they add to our general knowledge of the resultant effects of pollution discharged to streams and of the essential correctional measures necessary for stream improvement.

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